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(54) **IMAGE BASED CLINICAL TRIAL  
ASSESSMENT**

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(56) **References Cited**

**U.S. PATENT DOCUMENTS**

6,556,695	B1	4/2003	Packer et al.	
6,751,290	B2	6/2004	Salb	
7,043,415	B1 *	5/2006	Dunlavy	G06F 19/708
				702/19
7,251,609	B1 *	7/2007	McAlindon	G06F 19/363
				434/322
7,430,323	B2	9/2008	Shen et al.	
7,747,308	B2	6/2010	Hundley et al.	
7,822,240	B2	10/2010	Ayache et al.	
7,907,759	B2	3/2011	Hundley et al.	
7,972,266	B2 *	7/2011	Gobeyn	A61B 3/113
				348/222.1
8,103,073	B2 *	1/2012	Hundley	A61B 5/055
				128/920
8,548,823	B2 *	10/2013	Fueyo	G06F 19/321
				705/2
2005/0031210	A1	2/2005	Shen	

(Continued)

**OTHER PUBLICATIONS**

Leung, K. K., et al.; Automatic Quantification of Changes in Bone in  
Serial MR Images of Joints; 2006; IEEE Trans. on Medical Imaging;  
25(12)1617-1626 (provided by applicant).\*

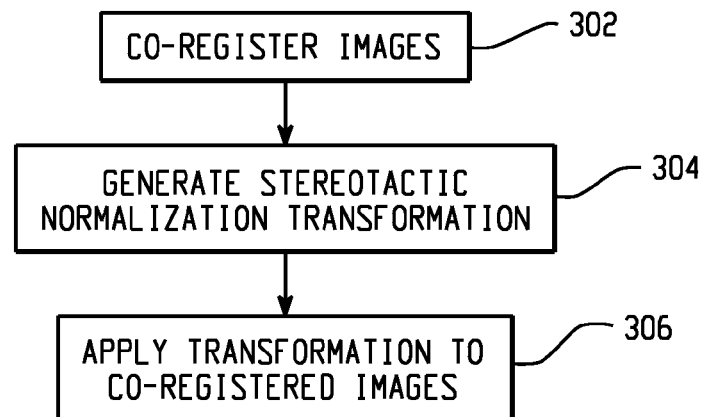
(Continued)

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(57) **ABSTRACT**

A method for assessing a treatment in a trial includes obtain-  
ing images generated from image data acquired at different  
times during a trial time period for a same region of interest of  
a subject. The treatment is administered to the subject for the  
trial. The method further includes co-registering the images  
and mapping the co-registered images to a reference image  
representing the region of interest. The method further  
includes generating a trial image of the region of interest  
showing at least one of structural or functional physiological  
changes that occurred during the trial time period based on the  
mapped co-registered images, and displaying the trial image.

**20 Claims, 3 Drawing Sheets**



(56)

**References Cited**

## U.S. PATENT DOCUMENTS

2005/0141757 A1\* 6/2005 Ayache ..... G06T 7/0012  
382/128  
2006/0173663 A1\* 8/2006 Langheier ..... G06F 19/3437  
703/11  
2007/0179377 A1\* 8/2007 Carlsen ..... G06T 3/0068  
600/407  
2007/0230757 A1\* 10/2007 Trachtenberg ..... A61B 18/20  
382/128  
2008/0292151 A1\* 11/2008 Kurtz ..... A61B 3/10  
382/128

## OTHER PUBLICATIONS

Wang, et al., "Medical Imaging in pharmaceutical clinical trials: what radiologists should know", Clinical Radiology, Livingstone, Harlow, GB, vol. 60, No. 10, Oct. 1, 2005.

Kaneta, T., et al.; Dementia clinical trials with longitudinal FDG PET: Improved statistical power using intra-subject registration; 2009; J. of Nuclear Medicine, Society of Nuclear Medicine; 50(suppl):26.

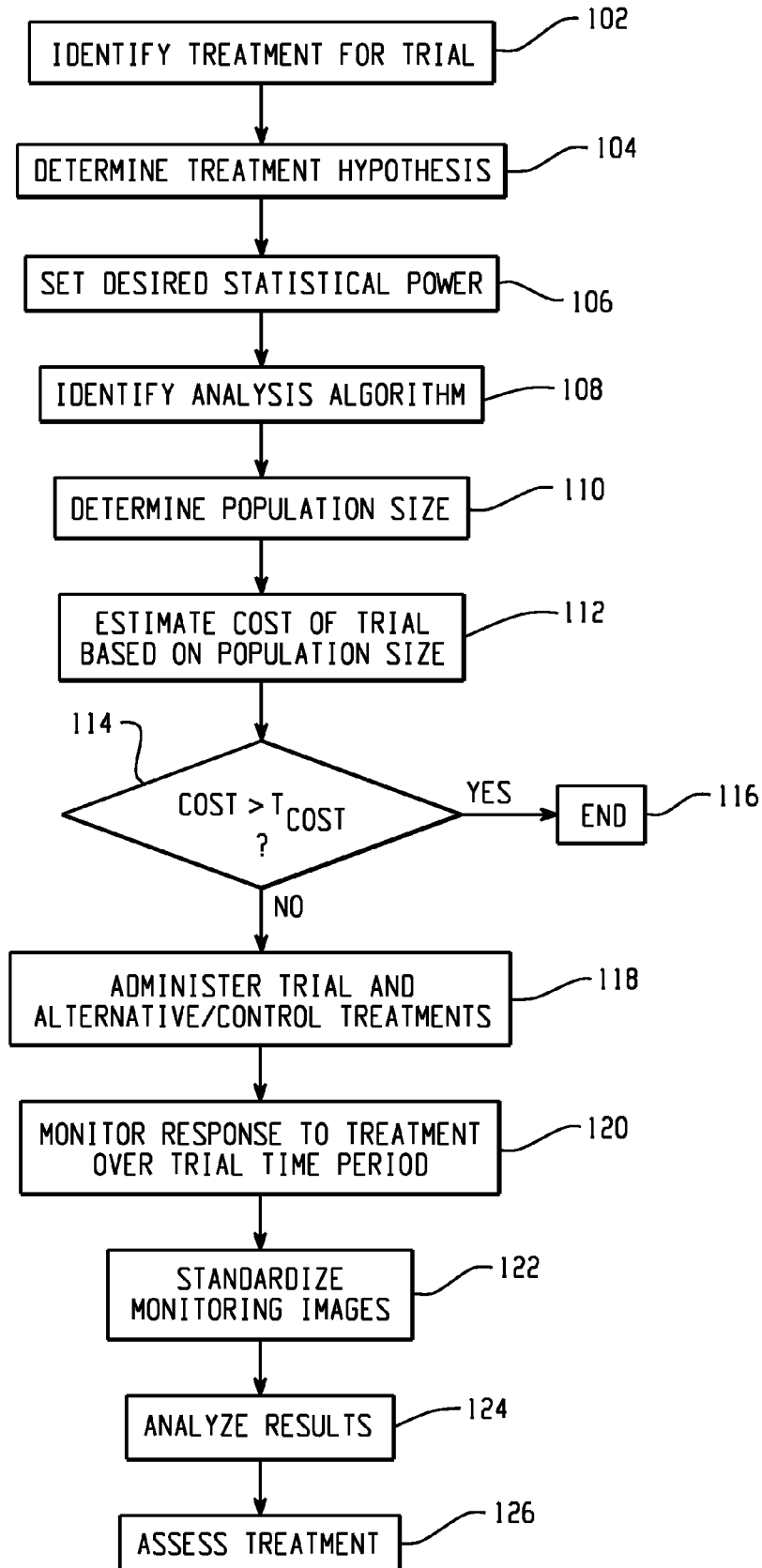
Leung, K. K., et al.; Automatic Quantification of Changes in Bone in Serial MR Images of Joints; 2006; IEEE Trans. on Medical Imaging; 25(12)1617-1626.

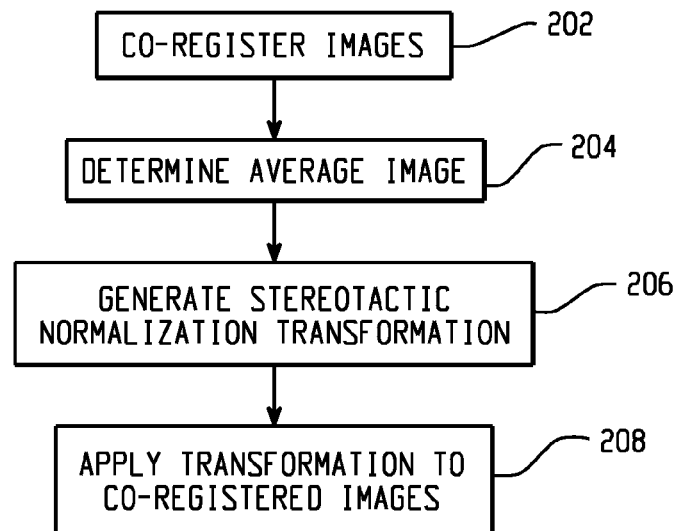
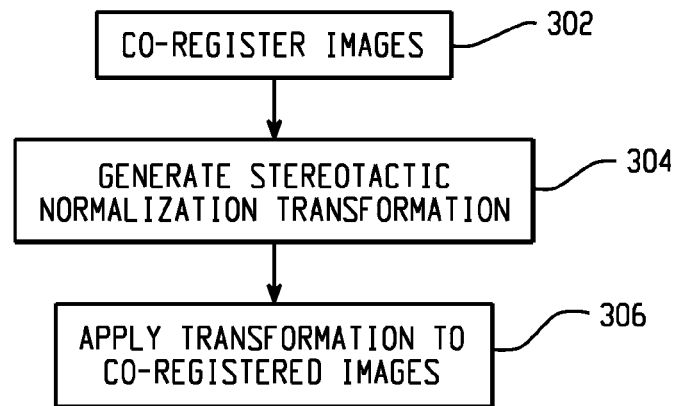
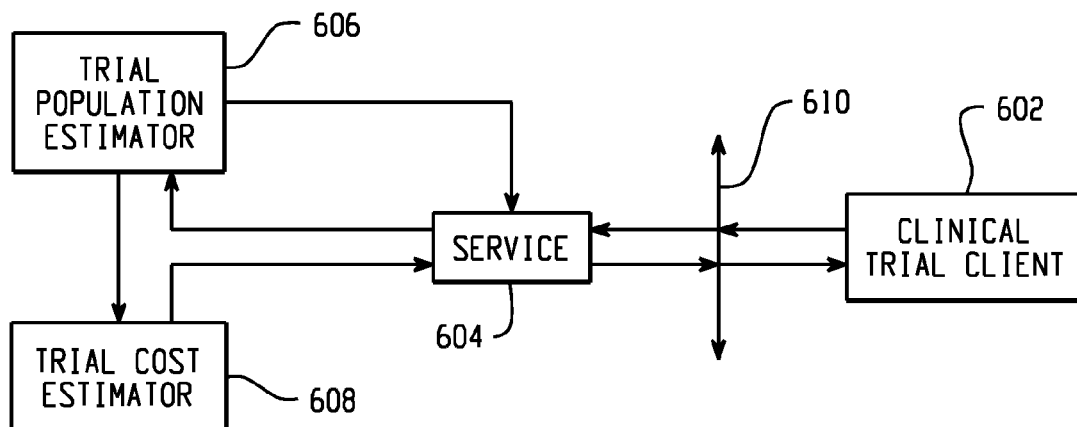
Lorenzo-Valdes, M., et al.; Atlas-Based Segmentation and Tracking of 3D Cardiac MR Images Using Non-rigid Registration; 2002; Lecture Notes in Computer Science (Proc. Medical Image Computing and Computer-Assisted Intervention) vol. 2488; pp. 642-650.

Rey, D., et al.; A Spatio-temporal Model-based Statistical Approach to Detect Evolving Multiple Sclerosis Lesions; 2001; Mathematical Methods in Biomedical Image Analysis; pp. 105-112.

Zijdenbos, A. P., et al.; Automatic "Pipeline" Analysis of 3-D MRI Data for Clinical Trials: Application to Multiple Sclerosis; 2002; IEEE Trans. on Medical Imaging; 21(10)1280-1291.

\* cited by examiner

*Fig. 1*

*Fig. 2**Fig. 3**Fig. 6*

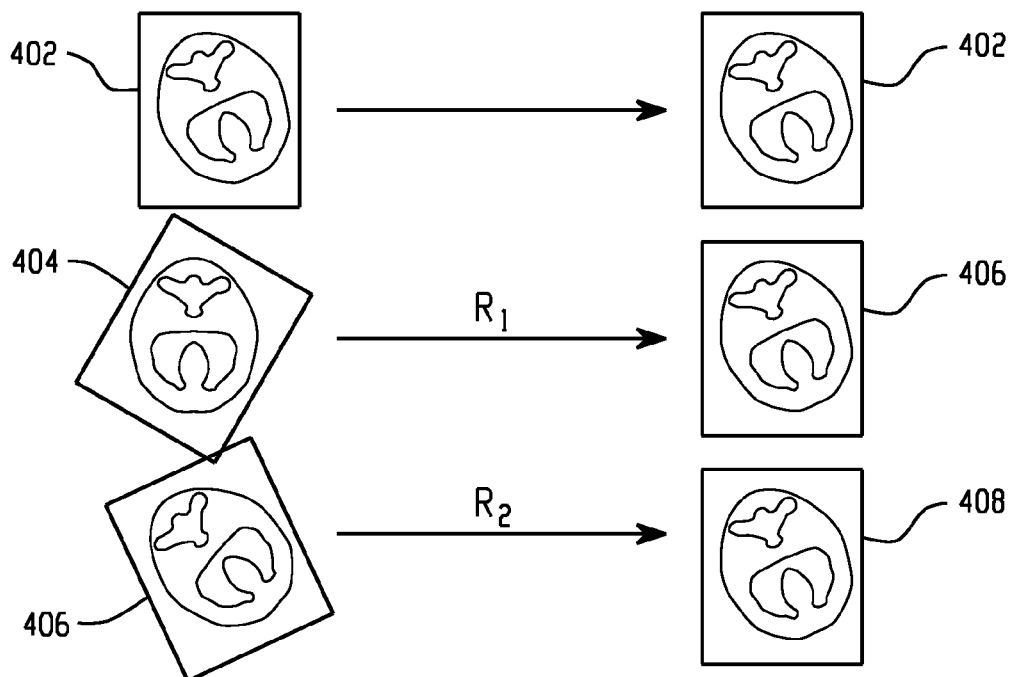


Fig. 4

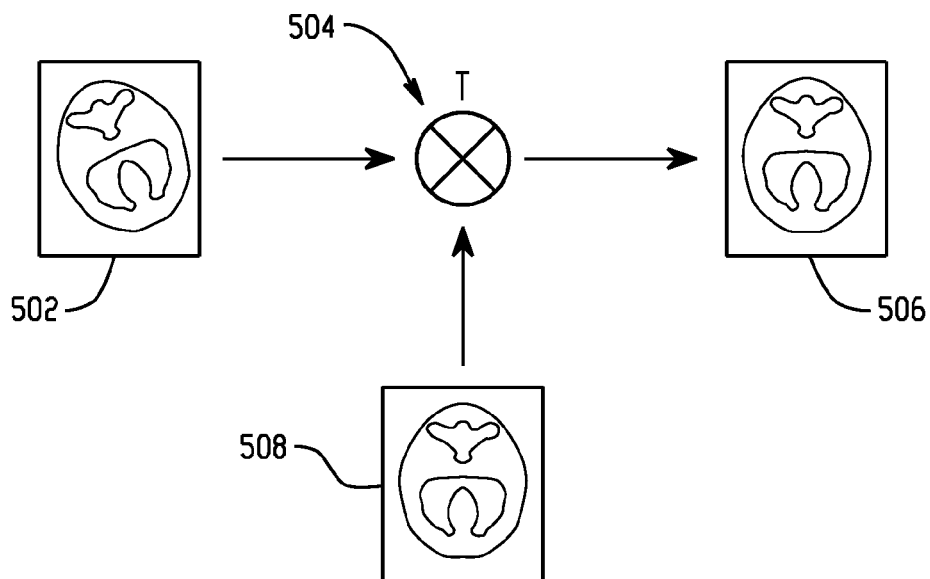


Fig. 5

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## IMAGE BASED CLINICAL TRIAL ASSESSMENT

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of U.S. Ser. No. 13/144,172 filed Jul. 12, 2011 which is a national filing of PCT application Serial No. PCT/IB2009/055614, filed Dec. 9, 2009, published as WO 2010/082096 A2 on Jul. 22, 2010, which claims the benefit of U.S. provisional application Ser. No. 61/144,231 filed Jan. 13, 2009, which is incorporated herein by reference.

### DESCRIPTION

The following generally relates to assessing clinical trials using medical imaging data.

Clinical trials in healthcare provide information that is used to determine the clinical efficacy of a new drug or device. A typical drug trial involves several subjects, some of which ingest the drug under trial and others of which ingest a placebo. The subjects are monitored over time for physiological changes, which are hypothesized, in response to the drug. The change resulting from the drug or the degree of change between the two groups of subjects is analyzed and used to test the hypothesis and determine the efficacy of the new drug.

Medical imaging can be used to monitor structural and/or functional changes in the subject in response to the drug. By way of example, longitudinal imaging, which involves acquiring images of the same anatomy for the same subject over time allows for the investigation of the affect of the drug on the subject over time. Quantitative imaging procedures currently serve as surrogate endpoints in clinical trials. A standard procedure for quantitative brain imaging is statistical brain mapping. In statistical brain mapping, the brain image of a subject is statistically compared to a control collective of brain images.

With one technique, a new drug is administered to some subjects and a placebo is administered to other subjects, and the subjects are scanned over time. The resulting images are spatially normalized to standard coordinates, and a statistical analysis is performed on the normalized images. The results can be mapped to a three dimensional model of the brain surface or a surface projected on the model. The statistical analysis may provide t-statistics or a z-score, which is a scalar value per voxel. A final image is rendered showing those voxels that have a statistical value above a given threshold. From such an image, the efficacy of the drug can be determined.

The literature notes that the cost of a clinical trial makes up as much as sixty percent (60%) of the total development cost of a new drug. A relatively high cost component of a trial is the number of subjects enrolled in the trial; more subjects leads to a more expensive trial. Lower variation results in higher statistical power, or a greater ability of the trial to reliably detect the magnitude of the effect of the drug relative to the placebo. Unfortunately, the number of subjects enrolled in a particular trial generally depends on the variability (or noise) of the trial assessment technique, with the number of subjects required for a trial and, thus the cost of the trial, increasing with increased variability.

Aspects of the present application address the above-referenced matters and others.

According to one aspect, a method for assessing a treatment in a trial includes obtaining images generated from image data acquired at different times during a trial time

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period for a same anatomical region of a subject. The treatment is administered to the subject for the trial. The method further includes co-registering the images and mapping the co-registered images to a reference image representing the scanned anatomical region. The method further includes generating a trial image of the anatomical region showing at least one of structural or functional physiological changes that occurred during the trial time period based on the mapped co-registered images, and displaying the trial image.

In another aspect, a computer implemented method for determining an efficacy of a treatment in a trial includes co-registering images corresponding to a same region of a subject to a baseline image via a single affine registration by way of computer. The images are acquired at different times after administering a trial treatment to the subject. The method further includes applying a computer implemented transformation to the co-registered images to fit the co-registered images to an anatomical model representing the anatomical region under consideration. The method further includes generating a value representing a physiological change in the region of interest based on the mapped co-registered images. The method further includes determining an efficacy of the treatment based on the value.

In another aspect, a system includes a trial population estimator that generates a first signal indicative of an estimated trial population size based on a given statistical power and an image analysis algorithm. The algorithm includes transforming co-registered images of a same region of interest of a subject administered a trial treatment to a model based on a same transformation. The system further includes a trial cost estimator that generates a second signal indicative of an estimated clinical trial cost as a function of the estimated trial population size, and a service that provides the second signal to a client over a computer network.

In another aspect, a system includes a service that generates a signal indicative of a trial image analysis algorithm based on a trial budget and a statistical power, both provided by a client over a network, wherein the algorithm includes transforming co-registered images of a same region of interest of a subject administered a trial treatment to a model based on a same transformation, and the service provides the signal to the client over the network.

Still further aspects of the present invention will be appreciated to those of ordinary skill in the art upon reading and understanding the following detailed description.

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIG. 1 illustrates an example clinical trial flow diagram.

FIG. 2 illustrates a first example image standardization technique.

FIG. 3 illustrates a second example image standardization technique.

FIG. 4 shows an example of co-registering images for a subject.

FIG. 5 shows an example of transforming a co-registered image.

FIG. 6 illustrates a clinical trial planning service.

FIG. 1 illustrates an example clinical trial flow diagram. The illustrated flow diagram provides for increased clinical trial statistical power or reduced clinical trial population for a given statistical power by decreasing clinical trial data variability.

At 102, a treatment for clinical trial such as a new pharmaceutical or device is identified. One or more preliminary

experiments can be conducted to gain insight for the planning of the clinical trial. This may include obtaining information about characteristics of suitable subjects for the trial (the trial population), comparative data such as alternative treatments and/or a placebo, clinical trial budgets, etc.

At **104**, a treatment hypothesis is determined. The hypothesis may include predicting results, determining a desired outcome, etc.

At **106**, a desired statistical power is set for the trial. The statistical power provides a quantitative measure of the ability of the trial to reliably detect the affect of the treatment.

At **108** an image analysis algorithm for the trial is identified based on the statistical power. In one instance, the algorithm includes affinely co-registering images for a subject of the trial and subsequently stereotactically normalizing each of the co-registered images based on an average image, as described in greater detail below in connection with FIG. **2**. In another example, the algorithm includes affinely co-registering images for the subject and subsequently stereotactically normalizing each of the co-registered images based on a reference, as described in greater detail below in connection with FIG. **3**.

The approaches of FIGS. **2** and **3** utilize a single estimated non-rigid (elastic) registration transformation to transform affinely co-registered images and can improve the statistical power of a clinical trial for a given trial population size relative to a configuration in which non-aligned (non co-registered) images are individually transformed via different non-rigid (elastic) registrations as the approaches of FIGS. **2** and **3** add relatively less variance to the post-processed images and thus provide relatively higher statistical power for the clinical trial. Alternatively, the trial population size can be reduced for a given statistical power. Individually transforming non co-registered images using different elastic registrations is not as accurate and adds more variation (noise) to the processed images, which decreases statistical power.

At **110**, a trial population size is determined based on the statistical power and the analysis algorithm. The size of the population generally increases with increasing variability and thus can be decreased using the algorithms of FIGS. **2** and **3**.

At **112**, an estimated cost of the trial is determined as a function of the population size.

At **114**, it is determined whether the estimated cost is less than a target population cost ( $T_{cost}$ ) of the trial. Alternatively, the estimated cost is added with the other costs of the trial and the aggregated cost is compared with the trial budget.

In this example, if the estimated cost is greater than the target cost, then the trial is not conducted and flow ends at **116**, and if the estimated cost is less than the target cost, then the trial proceeds.

At **118**, the trial and alternative/control treatments are administered to the subjects. By way of example, the trial treatment can be administered to a first group of the subjects. A placebo can be administered to a second different group of the subjects. Alternatively or additionally, one or more alternative treatments can be administered to one or more other groups.

At **120**, the subjects are monitored over time. In one embodiment, this includes acquiring image data through periodically scanning or imaging the subjects over some time during such as hours, days, weeks, months or years. For example, in one instance baseline images for the subjects are acquired before, during or shortly after administration of the trial treatment, alternative treatment and/or placebo.

Post trial treatment, alternative treatment and/or placebo administration image data or images generated therefrom are subsequently obtained over the trial period. The image can be

a positron emission tomography (PET), single photon emission computed tomography (SPECT), computed tomography (CT), magnetic resonance (MR), ultrasound (US), other medical and/or non-medical image.

At **122**, the resulting images for each subject are standardized in accordance with the image analysis algorithms identified at **108** as described in greater detail below. As noted above, examples of such algorithms are described in connection with FIGS. **2** and **3**. The images can be presented for display on a display of a computing device before and/or after standardization.

At **124**, the results of the trial are analyzed. In one instance, this includes performing a computer based statistical analysis. The statistical analysis may include determining a physiological (structural and/or functional) change for a region of interest over time for each subject via the standardized images. This includes measuring and recording a value representing a change between the images for each patient over time. The value may include information such a color or gray scale value representing a degree of change.

The value may be presented visually or graphically through one or more images and/or numerically through numeric characters. The identified change may correspond to a particular region of interest selected by a user or otherwise, and may include a single voxel, a plurality of voxels, or the entire image. The displayed image may only show pixels corresponding to changes greater than a threshold value, may highlight or otherwise emphasize pixels corresponding to changes greater than a threshold value, etc.

At **126**, the treatment is assessed based on the analyzed results. For example, the results can be used to assess the safety and effectiveness of the new medication or device on a specific kind of patient, of a different dose of a medication than that commonly used, of an already marketed medication or device for a new indication, to determine whether the new medication or device is more effective for a patient's condition than an already used, standard medication or device, etc. For example, if the difference is greater than a hypothesized difference, then the hypothesis is confirmed, and if the difference is less than the hypothesized difference, then the hypothesis is rejected.

FIG. **2** illustrates an example image standardization technique that can be employed in connection with act **122** of FIG. **1**. The technique includes generating a single estimated elastic transformation based on an average of co-registered images and applying this estimated elastic transformation to each of the co-registered images.

At **202**, the images for each subject are co-registered with each other using an affine registration. In one non-limiting instance, this includes identifying one of the images as a reference or baseline image, and the other images are co-registered to the reference image. The reference image can be the first image in time, the last image in time, or any image therebetween. The reference image may be manually selected by a user and/or automatically selected via computer executable instructions being executed by a computer processor.

Generally, prior to co-registration the images for a subject are not-aligned with respect to each other. During registration, the images are rotated and/or translated and/or geometrically scaled with respect to the reference image so that the anatomy therein is aligned. FIG. **4** shows an example in which a series of three non-aligned images are co-registered. The depicted 2-dimensional image is a representation of a 3-dimensional image. In this example, an image **402** is selected as the reference or baseline image, and images **404** and **406** are

registered with the image **402** based on respective registration transformation **R1** and **R2** to produce co-registered images **402**, **406** and **408**.

Returning to FIG. 2, at **204** an average image is generated. The average image is an average of the co-registered images and can be generated by summing the co-registered images and dividing the summation by the total number of summed images.

At **206** a stereotactic normalization elastic transformation is generated based on the average image and a model of anatomy of interest. In one instance, the transformation represents a mapping between the average image and an anatomical model of interest. A suitable transformation maps each image pixel to a known anatomical position.

At **208**, the elastic transformation is applied to each of the co-registered images. The transformation elastically transforms or warps each of the co-registered images to fit the model.

FIG. 5 shows an example in which a co-registered image **502** is transformed with a transformation **504** to generate a standardized image **506**. In this example, the transformation **504** is based on a template image **508**.

The resulting stereotactically normalized co-registered images can be analyzed as discussed above in connection with **124**.

FIG. 3 illustrates an example image standardization technique that can be employed in connection with act **122** of FIG. 1. The technique includes generating a single estimated elastic transformation based on a reference or baseline co-registered image and applying the estimated elastic transformation to the co-registered images.

At **302**, similar to **202**, the images for a subject are co-registered with each other using a rigid registration.

At **304**, one of the images is used to generate the stereotactic normalization transformation. The image may be the reference image for the co-registration or a different image. As discussed above, the transformation represents a mapping between the image and an anatomical model. Note that if the first image in time is used to generate the transformation, steps **302** and **304** may be exchanged in order, i.e. **304** first, then **302** for each additional image of the same subject.

At **306**, each co-registered image is transformed via the same stereotactic normalization transformation. The co-registered images can be transformed in parallel, for example, once all of the images are acquired, or sequentially as images are obtained.

The resulting stereotactically normalized co-registered images can be analyzed as discussed above in connection with **124**.

The approach of FIG. 2 generally provides higher statistical power relative to the approach of FIG. 3. However, if additional images are acquired for a subject after the elastic transformation is generated, then the transformation is recalculated to take into account the later acquired images.

As discussed herein, the approaches of FIGS. 2 and 3 may facilitate reducing trial population size and thus trial cost by improving statistical power through reducing variability in measurement. The following provides a non-limiting example. Assume a two-sided significance level ("p-value") of 0.05, a statistical power requirement of 0.8, and a hypothesized effect size of 10% between 2 groups of equal size. Also assume a mean outcome measure of 0.01 ( $\Rightarrow \Delta = 0.001$ ), with a standard deviation of 0.014 using the approaches of FIGS. 2 and 3 and a standard deviation of 0.015 using an approach where the images are not co-registered and each image is individually transformed with its own transformation. An approximated population size for the approaches of

FIGS. 2 and 3 is 3078, whereas an approximated population size for the other approach is 3533. Hence, using the approaches of FIGS. 2 and 3 would reduce the trial population size relative to the other approach.

Those of ordinary skill in the art will recognize that the various techniques described herein may be implemented by way of computer readable instructions stored on a computer readable storage medium accessible to a computer processor. When executed, the instructions cause the processor(s) to carry out the described techniques. Note that the medium need not be local to the processor; the instructions may be downloaded or otherwise accessed via a communication network such as the internet. The relevant computers may also be located remote from the imaging system, with the scan data transferred via a suitable network or other medium.

FIG. 6 illustrates an example clinical trial planning service. As shown, a clinical trial client **602** provides clinical trial information to a service **604**, which estimates a cost of the clinical trial based on the clinical trial information. In the illustrated example, the client **602** and the service **604** communicate electronically, via wire or wirelessly, through a computer network **610** such as the Internet, an intranet, etc. The service **604** may be subscription or otherwise based.

The clinical trial client **602** may be a financial or accounting client or other client that may determine or influence whether a clinical trial is conducted or not. In one instance, the clinical trial client **602** provides information such as a desired clinical trial statistical power, an algorithm used to analyze the data, and/or known variations with the algorithm. The algorithm may be a statistical power enhancing algorithm such as those described in connection with FIGS. 1-3 above.

This information is provided to a clinical trial population determiner **606**, which estimates the population for the trial based on the desired statistical power, the algorithm used to analyze the data, and/or the known variations. A cost estimator **608** estimates a cost of the trial as a function of trial population. A signal indicative of the cost estimate is provided to the clinical trial client **602** by the service **604**. The cost estimate may include alternatives such as a cost estimate for a clinical trial with greater statistical power due to the analysis algorithm and a cost estimate for a clinical trial with a reduced population at the desired statistical power due to the analysis algorithm.

In another embodiment, the clinical trial client **602** provides information such as a desired clinical trial statistical power and a budget allocated for a trial population, and the service **602** determines a suitable algorithm(s) and/or an estimated population size based on the information. The service **604** provides one or more signals indicative of the suitable algorithm(s) and/or the estimated population size to the client **602**. In this embodiment, the cost estimator **608** can be omitted.

The invention has been described with reference to various embodiments. Modifications and alterations may occur to others upon reading the detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

The invention is claimed to be:

1. A computer implemented method for determining an efficacy of a treatment in a trial, comprising:

co-registering images of a set of images corresponding to a same region of interest of a subject to a baseline image via an affine registration by way of computer, wherein the baseline image is from the set of images and the set of images are acquired at different times after administering a trial treatment to the subject;



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applying a computer implemented transformation to the co-registered images to fit the co-registered images to an anatomical model representing the region of interest; generating a value representing a physiological change in the region of interest based on the mapped co-registered images; and

determining an efficacy of the treatment based on the value.

2. The computer implemented method of claim 1, wherein the value is compared to a predetermined threshold value.

3. The computer implemented method of claim 1, wherein the value represents one or more voxels in the region of interest.

4. The computer implemented method of claim 1, further comprising:

co-registering a second set of images corresponding to the same region of interest of a second subject, wherein the images are acquired at different times after administering a second treatment or a placebo to the second subject;

applying the computer implemented transformation to the second co-registered images to fit the second co-registered images to the anatomical model representing the region of interest;

generating a second value representing a physiological change in the region of interest based on the second mapped co-registered images; and

determining the efficacy of the treatment based on a difference between the value and the second value.

5. The computer implemented method of claim 4, further comprising displaying a difference image visually presenting the difference between the value and the second value.

6. The computer implemented method of claim 1, further comprising visually displaying the value.

7. The computer implemented method of claim 1, further comprising superimposing indicia representing the value over an image of the region of interest.

8. The computer implemented method of claim 1, wherein the co-registration includes an affine registration.

9. The computer implemented method of claim 1, wherein the transformation includes a single elastic fitting.

10. The computer implemented method of claim 1, wherein a trial population size is determined by a trial population estimator based on a given statistical power and an

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image analysis algorithm, which includes transforming the co-registered images to the anatomical model.

11. The computer implemented method of claim 10, wherein an estimated trial cost is determined by a trial cost estimator based on the estimated trial population size.

12. The computer implemented method of claim 11, wherein the trial population estimator and the trial cost estimator are part of a networked based service.

13. The computer implemented method of claim 12, wherein the service determines a suitable image analysis algorithm based on a trial budget and a predetermined statistical power.

14. The computer implemented method of claim 1, further comprising:

generating the computer implemented transformation by generating a transform for only a single one of the co-registered images, wherein the generated transform is applied to fit each of the co-registered images to the anatomical model.

15. The computer implemented method of claim 1, further comprising:

generating the computer implemented transformation by taking an average of the co-registered images and generating a transform for the average image, wherein the generated transform is applied to fit each of the co-registered images to the anatomical model.

16. The computer implemented method of claim 1, wherein determining the efficacy includes assessing a safety of the treatment.

17. The computer implemented method of claim 1, wherein determining the efficacy includes assessing an effectiveness of the treatment.

18. The computer implemented method of claim 1, wherein determining the efficacy determining whether a new treatment is more effective than a previously used treatment.

19. The computer implemented method of claim 1, wherein the co-registered images are transformed in parallel once all of the images are acquired.

20. The computer implemented method of claim 1, wherein the co-registered images are transformed sequentially as images are obtained.

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